(12) UK Patent Application (19) GB (11) 2 187 267 (13) A

(43) Application published 3 Sep 1987

(21) Application No 8531828

(22) Date of filing 24 Dec 1985

(71) Applicant
Ferranti plc

(Incorporated in United Kingdom)

Bridge House, Park Road, Gatley, Cheadle, Cheshire

(72) Inventor
Peter Hodges

(74) Agent and/or Address for Service
A. R. Cooper,
Patents & Legal Department, Bridge House, Park Road, Gatley, Cheadle, Cheshire

(51) INT CL⁴
F42B 8/00

(52) Domestic classification (Edition I):
F3A 1C1
F3C GX

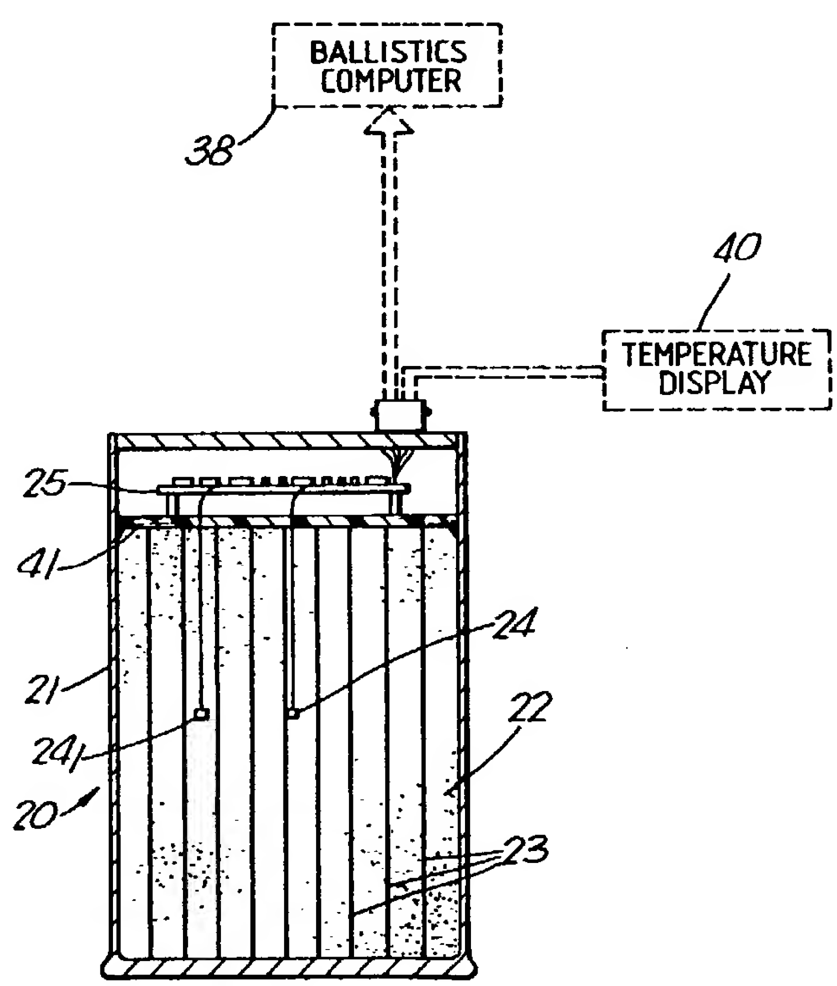
(56) Documents cited
None

(58) Field of search
F3A
F3C
Selected US specifications from IPC sub-classes F41F F41G

(54) Estimating gun propellant charge temperature

(57) An estimate of the core temperature of a propellant charge used in a large calibre (e.g. tank) gun, which core temperature is a prime factor determining explosive efficiency of the charge and actual projectile range and lags behind changes in ambient temperature, is obtained by providing a container 21 such as an ammunition case containing an explosively inert material 22, such as sand, packed to have a thermal conductivity and mass corresponding to the propellant material normally held therein. One or more electrical temperature sensors 24, 24_1 are disposed in the inert material in the vicinity of the core, and possibly at other depths from the surface, to give an estimate of the instantaneous temperature at the core and/or a temperature profile through the material which corresponds to the propellant of an ammunition round subject to the same ambient temperature conditions. The temperature at a predefined burn zone of such a propellant charge is determined by sensor signal processing means and applied to a fire control computer or the sensed temperature signals are applied to the computer which effects the estimate.

Fig. 3.



The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

GB 2 187 267 A

1/4

2187267

Fig.1.

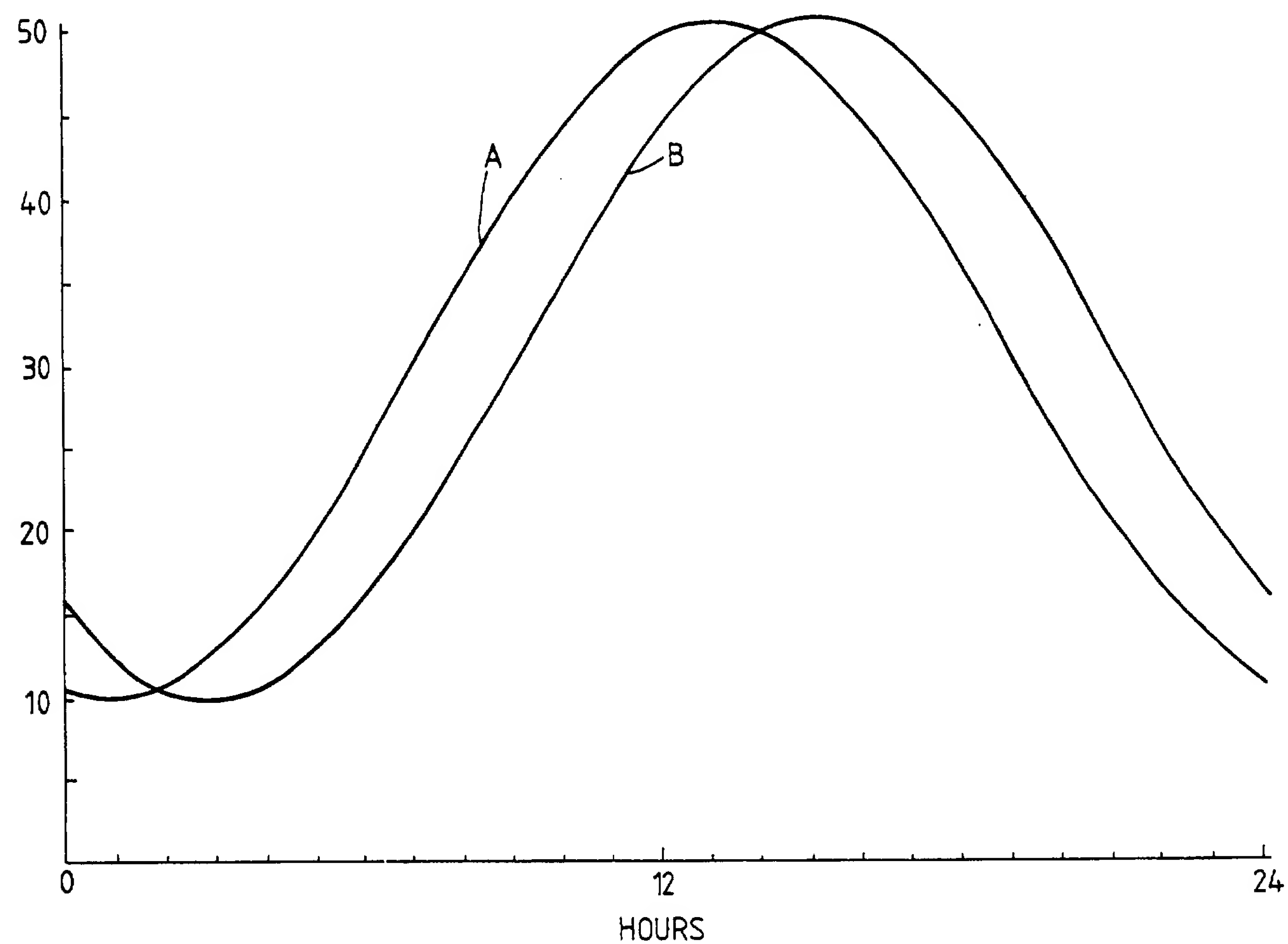
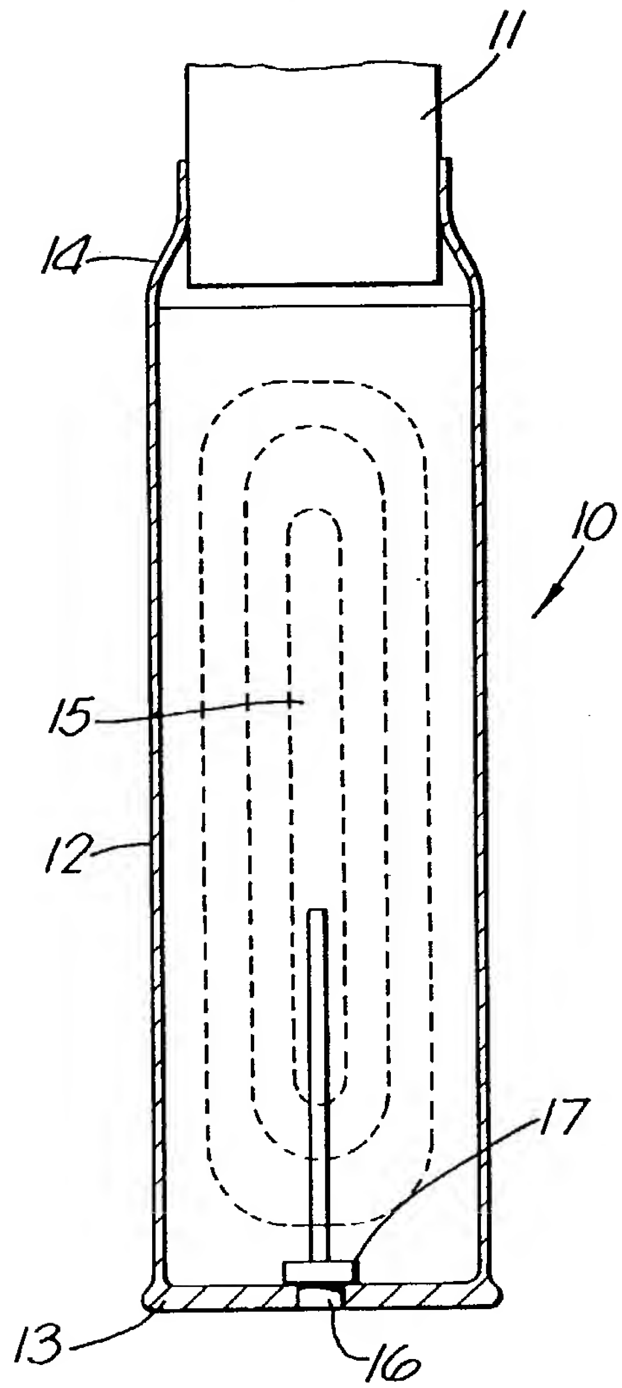


Fig. 2(a).



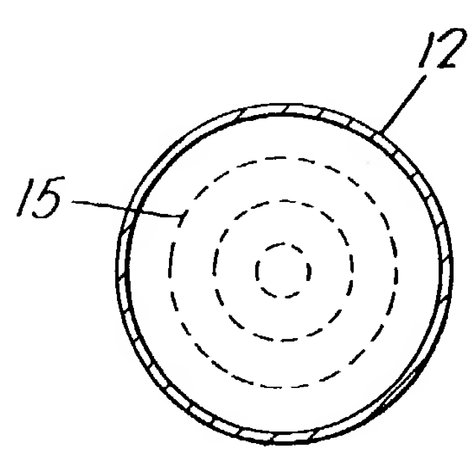
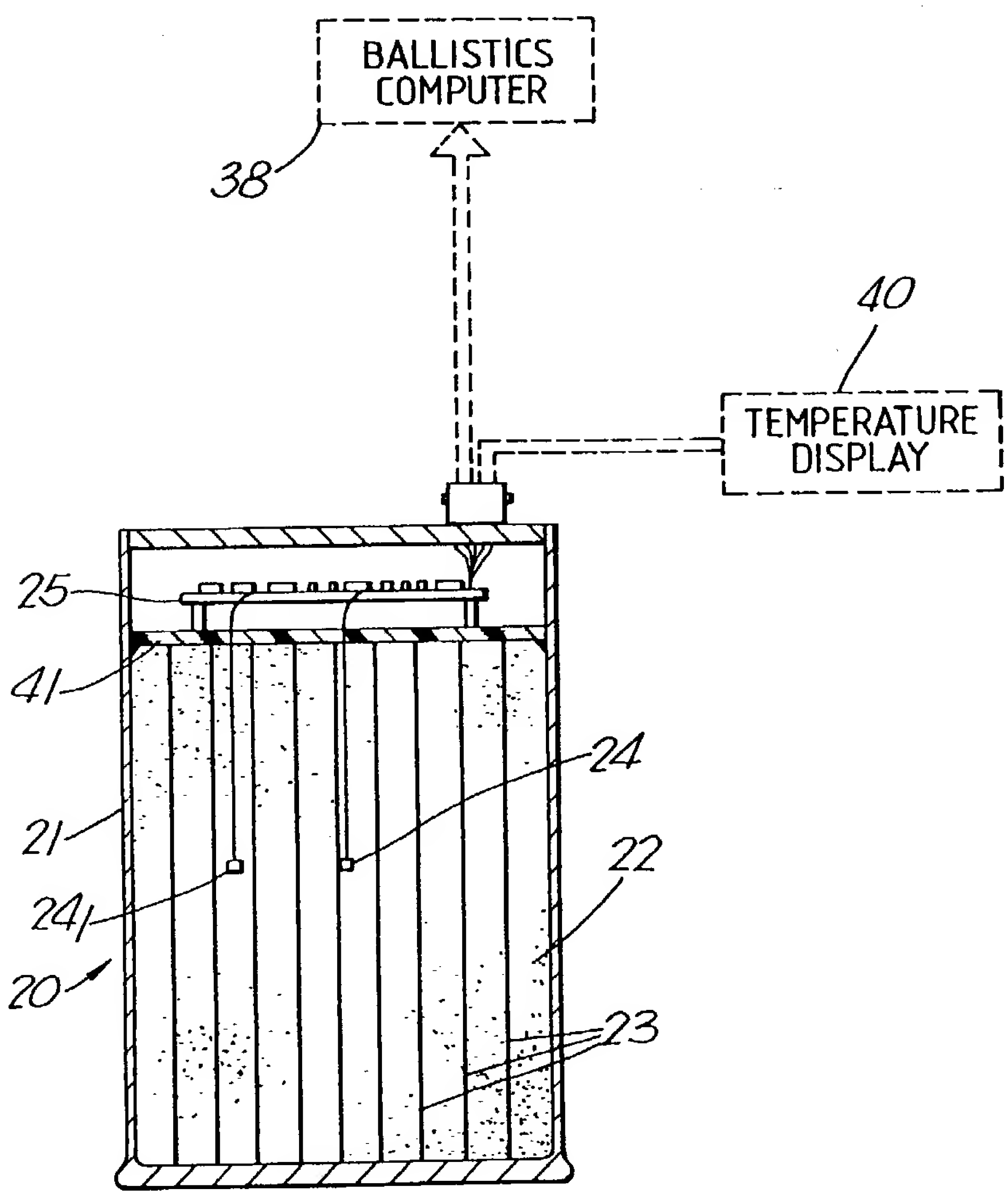


Fig. 2(b).

Fig. 3.


BALLISTICS COMPUTER
38
40
TEMPERATURE DISPLAY
25
41
24
21
22
24
20
23

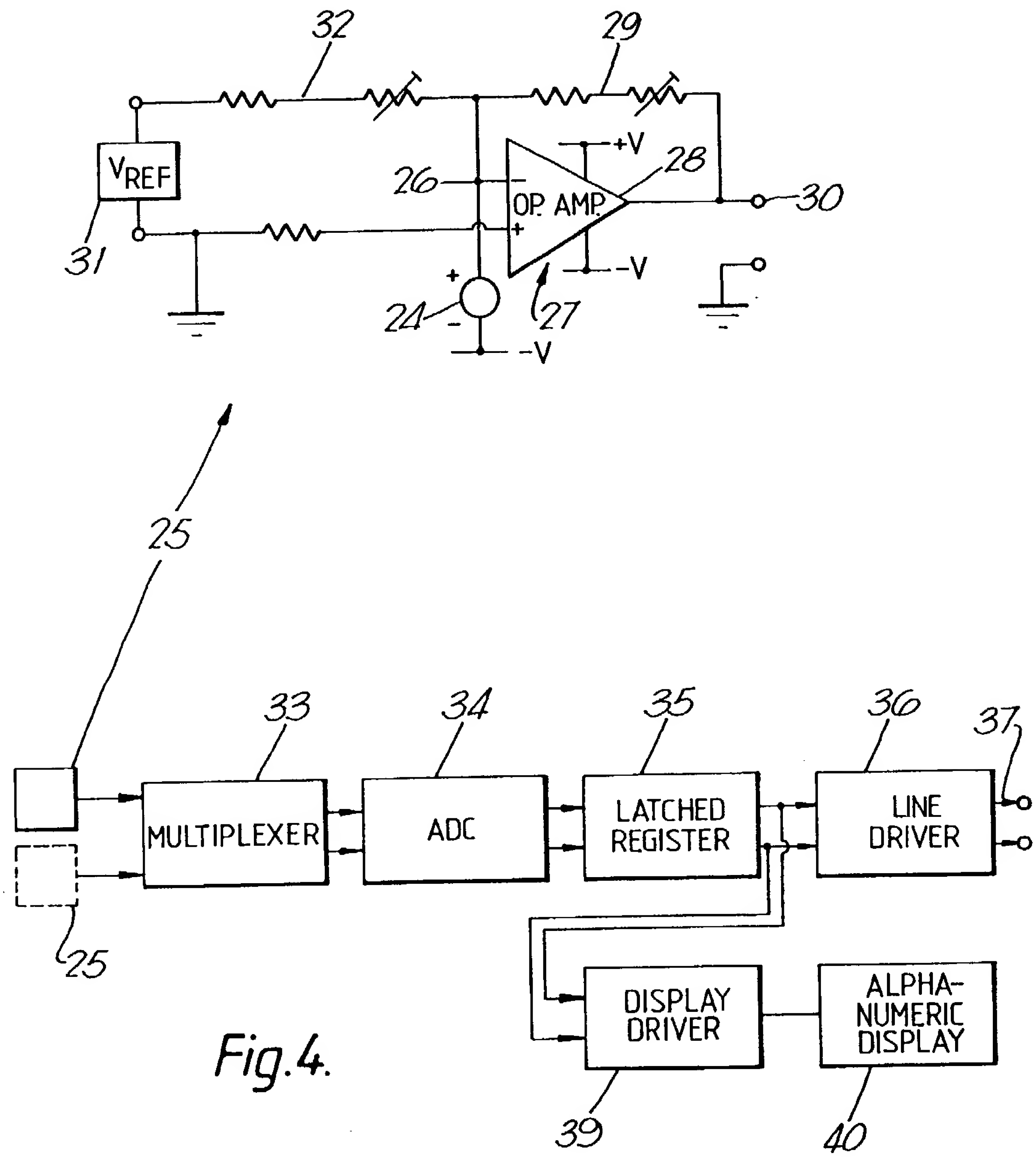

32
29
V_{REF}
26
OP. AMP.
+V
28
30
31
+
24
-
-V
27
25
33
34
35
36
37
MULTIPLEXER
ADC
LATCHED REGISTER
LINE DRIVER
25
DISPLAY DRIVER
ALPHA-NUMERIC DISPLAY
39
40

Fig.4.

SPECIFICATION

Estimating gun propellant charge temperature

This invention relates to improving the accuracy of large calibre guns and in particular to estimating the temperature of propellant charges used in such guns.

Gun accuracy is affected by many factors associated with the gun, environmental conditions and the ammunition and fire control computers are known which measure many of the influencing parameters and employ them in algorithims defining the ballistic behaviour of the system.

One of the many influences on gun accuracy and which is the subject of this specification is the temperature of the propellant charge of the gun ammunition and in practice the effect of variation of environmental temperature on such a propellant charge.

Ammunition employed in large calibre guns, that is, in the range 90-140mm, may be considered as taking one of two forms determined by the nature of the propellant charge. In one form the projectile is loaded separately into the barrel by way of the breech, the breech thereafter being loaded with one or more "bag charges" of propellant material. The bags have a flexible wall which serves only to contain the propellant material for handling, the shape of the charge after loading being defined by and contained by the breech. The other form is a cased ammunition round in which the propellant material is contained in a cylindrical metal case one end of which is closed onto a projectile to form an unitary ammunition round loaded into the gun such that the case containing the propellant charge is located in the breech and the projectile extends into the barrel.

The propellant material is usually in the form of granules which may take the form of elongate solid cords, ribbons, tubes or slotted tubes amongst other known configurations which relate the rate of burning to surface dimensions.

Detonation of both types of propellant charge are similar in that a priming detonation is effected at the core of the charge by igniting the surface portion of each granule which then burns to its own core at a rate dependent upon the initial charge temperature and pressume developed during combustion.

Although different propellant granule configurations and materials are employed to produce different desired detonation pressures and rates of burn the mechanism of burning is substantially the same and dependent upon the temperature of the granules at the commencement of their combustion, that is, the effective temperature of the core region of the propellant charge as a unit.

The dependence of explosive efficiency upon temperature is important not in respect of the efficiency of the gun per se but in respect of anticipating the distance travelled by any particular projectile round fired by the gun.

In particular, the hotter the propellant the greater the explosive force and consequently greater the range of a projectile launched thereby. In a combat situation wherein a specific range is sought the effect of increased charge temperature is to cause the projectile to overshoot the target whereas a decreased charge temperature will cause the projectile to undershoot.

The effects of charge temperature are presently taken into account in ballistic computation but usually it is assumed that either the charge temperature has a fixed value determined for average operating conditions or is estimated manually by reference to ambient air temperature.

Neither of these methods reflect the true relationship between propellant charge temperature and the operating environment.

It will be appreciated that the weight of charge material required for large calibre guns has a significant thermal mass and depending on the thermal conductivity of the material and the structure of the charge a temperature gradient may exist between the outer portion of the charge and its core such that the temperature of the charge material at an effective detonation burn zone in the vicinity of the core is not readily related to the instantaneous ambient air temperature.

In any diurnal cycle, and particularly in countries that experience extreme changes in environmental temperature, the temperature of the propellant will tend to lag behind that of the ambient air and such a thermal lag is shown graphically in Figure 1 which relates the air temperature (ordinate) to the diurnal cycle time (abscissa), the curve A representing the ambient air temperature and curve B representing the temperature at some point within the propellant charge.

Clearly a measurement of the ambient air temperature may be inaccurate in representing propellant temperature and crude efforts have been made to improve the accuracy of propellant temperarure estimation by measuring the temperature of the interior of a spent ammunition case. Although this takes into account the temperature lag resulting from its thermal mass, such a case is normally a good thermal conductor in comparison with the propellant material and provides a limited improvement in estimation accuracy.

It is an object of the present invention to provide a method of more accurately estimating the operational temperature of a gun propellant charge for ballistic computation, and a charge temperature estimating arrangement, that is simple and provides a better estimate than hitherto employed.

According to a first aspect of the present invention a large calibre gun propellant charge temperature estimating arrangement includes a container of explosively inert material having a thermal mass and thermal conductivity corresponding to that of a real propellant charge for which a fire control computer of the gun is set, and temperature sensing means disposed in the body of the inert material operable to produce electrical signals indicative of the temperature of at least one point thereof.

According to a second aspect of the present invention a method of estimating the temperature of a propellant charge of a large calibre gun comprises providing a container of explosively inert material disposed and dimensioned such that the thermal conductivity and thermal mass corresponds to a real propellant charge for which a gun fire control computer is set, locating the dummy charge in a holding area for ammunition to be fired by the gun and sensing the temperature of the inert material at least one point within the container and representing the sensed temperature for application to the fire control computer.

Embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a graphical representation of the variation of propellant charge temperature as a function of diurnal ambient air temperature,

Figure 2(a) is a sectional elevation through a cased ammunition round showing temperature contours within the propellant charge,

Figure 2(b) is a cross-section through the ammunition case of Figure 2(a) also showing temperature contours within the propellant charge,

Figure 3 is a sectional elevation through a propellant charge temperature estimating arrangement according to the present invention, and

Figure 4 is a circuit diagram of signal processing circuit for the signals produced by the temperature sensors of Figure 3.

It will be appreciated that in the most general sense both cased and bag forms of propellant charges consist of predetermined quantities of explosive propellant material contained for storage, handling and loading and for the purpose of describing the invention it is convenient to consider principally one form only, a cased round.

Referring to Figures 2(a) and (b) a conventional cased ammunition round 10 comprises a projectile or shell 11 supported by a shell case 12. The shell case is formed of a cylinder closed at one end 13 and of greater diameter than the projectile, the neck 14 of the case being constricted to grip the projectile. The case 12 contains a predetermined weight of propellant material chosen with respect to the intended range and projectile weight forming the charge. The propellant material may be chosen from one of a number commonly used, for example nitrocellulose granules or solid cordite and in the case of a solid may be disposed in the casing in one of several known arrangements, for example, ribbon, tube, slotted tube or cord.

The propellant, whether solid or granules in close physical proximity may be considered to a first approximation as a homogeneous material filling the casing, said material having a known thermal conductivity and thermal capacity which defines the thermal mass of the charge.

Figures 2(a) and 2(b) show by means of dotted lines 14 the distribution of temperature contours which define a temperature gradient between the case wall, in contact with ambient air, and propellant core, that is, a variation of temperature with depth into the propellant from the outer surface, when the round is moved from a place at which it has acquired a uniform temperature to one of different temperature or where the environmental temperature in which it is stored changes.

At any time during gun operation, say in a tank, a plurality of rounds of ammunition will be readied for firing and stored in a holding area. As ambient temperature within the holding area varies with time the temperature of the charge propellant, particularly that in the vicinity of the core 15, lags behind in the manner described above and illustrated in Figure 1.

When such an ammunition round is subsequently fired the propellant charge is detonated so that the explosive pressure developed in the case 12 by its combustion expels the projectile 11 from the case and forces it along the barrel. Detonation of the propellant charge is effected by impact of a firing pin (not shown) against a portion 16 of the base adjacent which portion, and within the case 12 is a percussion sensitive ignition charge 17 extending possibly into the core of the main propellant charge.

Upon ignition a burn zone develops which travels through the propellant material from the ignition charge, essentially from and along the core, depending upon the precise structural nature of the propellant charge.

As outlined above the amount of energy released at the burn zone is a function of the propellant temperature prior to its combustion and in order to utilise the charge temperature in the ballistic calculation of the fire control computer the computer needs to be provided with an estimate of the propellant temperature in the vicinity of the burn zone.

A propellant charge temperature estimating arrangement in accordance with the present invention is shown at 20 in the sectional elevation of Figure 3.

The arrangement comprises a container 21 which may be formed of a shell case of the type used for the real ammunition, and containing an explosively inert material 22, such

as sand, which has a thermal conductivity and thermal mass substantially equal to, or at least of the same order of magnitude as, that of a real propellant charge. Preferably the inert material 22 is disposed within the core 21 in a manner corresponding to the propellant material shown in Figure 2. If the propellant material is a homogeous solid loose sand may be simply packed into the case to a suitable density whereas if the propellant material is granular as being essentially a solid arranged with internal surfaces, e.g. packed tubes, then to a second degree of approximation a series of correspondingly shaped baffles, such as 23 may be located in the container to mimic the changes in thermal condutivity across such boundaries. Thus not only does the inert material behave thermally like the charge propellant but also the effects of its loading form within the case correspond to those which exist in the real ammunition charge.

The container also contains temperature sensing means in the form of one or more temperature sensors 24, 24_1 which are disposed in the body of the inert material and produce electrical signals, indicative of the temperature of the inert naterial in their vicinity. The signals are applied to electrical signal processing means, at least a first stage of which is shown at 25 and carried within the container 21.

The principal temperature sensor 24 is located substantially at the core of the container displaced both from the sides and ends of the container in accordance with the temperature contours shown in Figure 2(a) and any additional ones are located at decreasing depths from the outer (case) surface. The one additional sensor 24_1 shown is located midway between the case and surface of the inert material.

A further temperature sensor (not shown) may be in contact with the metal case 21 and effectively determine ambient temperature if required and if not available from other sources.

In operation the container is located in or near the aforementioned holding area with the readied ammunition where it, and the ammunition, are subjected to the same variations in temperature. The use of a shell case for the container makes storage in an ammunition rack in the holding area convenient if space is available. Each temperature sensor 24, 24_1 etc. provide signals to a circuit 25 which is shown in greater detail in Figure 4.

The temperature sensor 24 may comprise a semiconductor temperature sensor type 950 which provides a substantially linear signal variation with temperature. The sensor is connected to a summing junction 26 of an inverting summing amplifier 27, formed of operational amplifier 28 having a resistive feedback network 29 between output terminal 30 and the summing junction 26. A reference voltage from source 31 is also applied to the summing junction 26 by way of resistive network 32.

The resistance of the reference and feedback paths may be adjusted with the temperature sensor at one or more preset temperatures to establish the linearity of the circuit over the expected operating range of the sensor. The circuit 25 thus provides an analog signal representing sensor temperature.

The circuit 25 has its output terminal 30 connected by way of an optional multiplexer 33 to an anlog to digital converter (ADC) 34. The digitised temperature values are fed by way of a latched register 35 to line driver 36 and thence by suitable lines 37 (such as an RS232 configuration) to the ballistics computer shown generally at 38 in Figure 3.

Alternatively or in addition, the digital temperature signals from register 35 may be fed by way of a display driver 39 to an alphanumeric display arrangement 40 for normal interpretation.

If a plurality of temperature transducers are employed the signals they provide define a temperature profile or gradient existing between the outer surface and core of the inert material. Each circuit 25 then derives said signals at the predetermined location points of the sensors which are digitised by input to the multiplexer 33. The signals enable a temperature profile to be derived for the container and therefore enable the temperature to be effectively estimated at any other predetermined point within the inert material. The estimate is conveniently derived by the fire control computer 38 although it may of course be derived separately therefrom.

It will be appreciated from Figure 2 that the temperature contours define a temperature profile which extends from the casing to the core both at its ends and along the length of the charge, and apart from the end portions, the length of the charge makes little difference to its thermal behaviour other than to contribute to its thermal mass. Accordingly it will be appreciated that the container 21 shown in Figure 3 may be shorter than the real round case 12, shown in Figure 2, providing the temperature contours towards the end of the charge are not disturbed by the shortening and the omitted inert material is replaced by a suitable thermal mass. In the arrangement shown in Figure 3 a block 41 of resin bonded paper, such as paxolin, may be employed as such a thermal mass and to separate the inert material 22 from the circuit 25.

It will be understood that although it is convenient to employ a real shell case as the container, both from the point of view of its dimensions and its thermal properties, the container may be specially fabricated for the purpose and/or be formed of different material having suitable thermal properties.

Similarly it will be appreciated that the ex-

plosively inert material may be other than sand and be selected in accordance with the thermal properties of the propellant charge in the real rounds, as may the internal structure of the container and disposition of inert material in it. The inert material may be a solid formed into a disposition corresponding to solid propellant granules as regards surfaces and the like. For example, solid propellant granules formed from a plurality of tubular sticks may be represented by similar sticks of a suitable wood, such as mahogony.

Although it is convenient to form the dummy charge of a container having the same cross-sectional dimensions and structure as a real charge with directly corresponding thermal properties between inert and propellant materials it will be appreciated that if desired alternative materials may be selected to provide thermally equivalence with the propellant charge whilst having different dimensions, enabling a possibly smaller arrangement to be produced. This may be particularly suitable where storage space for the container is restricted.

The arrangement provides an estimate of propellant charge temperature at a fixed or selectable point within the charge for any ammunition round subject to the same ambient temperature. However, it is sometimes necessary to hold a round in the breech for some time prior to firing and the effect of an elevated breech temperature will alter the propellant charge temperature as a function of time in the same manner as an ambient air temperature rise. Accordingly, the arrangement may include a temperature sensor of the gun barrel breech and provide a signal thereof to the signal processing means which processing means is responsive to the temperature difference between the container 21 (or ambient temperature if this is measured instead) and the breech and to the time of holding the propellant charge in the breech to produce a modified estimate of the propellant charge temperature based upon the known reaction to temperature changes of the inert material.

There will of course be a thermal gradient existing through the wall of the breech so that if the temperature is measured by an external sensor compensation will be required in accordance with such a temperature gradient and may be predetermined in accordance with test firings. The estimated or measured internal breech temperature is then used as the basis of modifying the measured temperature in the inert material in the container.

In the above described embodiment and variations thereof it has been assumed that the propellant charge employed is that of a cased round as shown in Figure 2. It will be appreciated that the propellant material may be in the form of a bag charge, the container of the temperature estimating arrangement likewise having a flexible bag-like structure in which an explosively inert material, such as sand, is held in a manner corresponding to that for real charges. Preferably however some structural form is preferred for the container, although it may retain the thermal characteristic of the bag, in order to define the locations therein of the, or each, temperature sensor.

If the tank employs different types of ammunition then a corresponding temperature estimating arrangement will be required for each type. This may be achieved by having a plurality of different inert material-filled containers with the correct thermal properties, each supplying temperature signals to the ballistics computer, or by storing in the computer relationships between the thermal properties of the different types of propellant charges so that a single measuring arrangement as described above may be employed to provide signals characteristic of one charge type but from which are readily deduced the temperature characteristics of different charge types.

CLAIMS

1. A propellant charge temperature estimating arrangement including a container of explosively inert material hving a thermal mass and therma conductivity corresponding to that of a real propellant charge for which a fire control computer of the gun is set, and temperature sensing means disposed in the body of the inert material operable to produce electrical signals indicative of the temperature of at least one point thereof.

2. An arrangement as claimed in claim 1 in which the container has cross sectional dimensions substantially equal to those of a propellant charge container and the explosively inert material exhibits a thermal mass and conductivity substantially equal to said propellant charge and is packed in the container in a manner corresponding to the package of propellant material in a said real charge.

3. An arrangement as claimed in claim 1 or claim 2 in which the container is a container as used for the propellant charge.

4. An arrangement as claimed in claim 3 in which the container is a shell case.

5. An arrangement as claimed in claim 4 in which the shell case of the container is shorter than one of a real ammunition round.

6. An arrangement as claimed in any one of claims 1 to 5 in which the container is adapted to be operatively located in a holding rack of propellant charges.

7. An arrangement as claimed in any one of the preceding claims in which the sensing means comprises at least one thermo electric temperature sensor disposed substantially in the core of the inert material.

8. An arrangement as claimed in any one of the preceding claims in which the sensing means comprises a plurality of temperature sensors located throughout the container each operable to produce electrical signals repre-

sentative of the temperature of the inert material at their locations.

9. An arrangement as claimed in claim 7 or claim 8 in which the sensing means includes signal processing means responsive to the electrical signals of the, or each, temperature sensor to produce a representation of a temperature profile through the contained inert material.

10. An arrangement as claimed in any one of the preceding claims in which the explosively inert material is a dry granular material.

11. An arrangement as claimed in claim 10 in which the granular material is sand.

12. An arrangement as claimed in claim 10 or claim 11 when dependent on claim 4 or claim 5 in which the container is provided within internal baffles in order to dispose the granular material within the container in a manner corresponding to the disposition of a solid propellant material within a shell case.

13. An arrangement as claimed in any one of the preceding claims in which the, or each, sensor of the sensing means comprises a semiconductor device operable to produce an output voltage proportional to the temperature of the adjacent material.

14. An arrangement as claimed in any one of the preceding claims in which the temperature sensing means includes a sensor of the temperature of the gun barrel breech and is responsive to the temperature difference between the container and the breech and to the time of holding of a propellant charge in the breech to produce a modified estimate of propellant charge temperature.

15. A propellant charge temperature estimating arrangement substantially as herein described with reference to, and as shown in, Figures 3 and 4 of the accompanying drawings.

16. A method of estimating the temperature of a propellant charge of a large calibre gun comprises providing a container of explosively inert material disposed and dimensioned such that the thermal conductivity and thermal mass corresponds to a real propellant charge for which a gun fire control computer is set, locating the dummy charge in a holding area for ammunition to be fired by the gun and sensing the temperature of the inert material at at least one point within the container and representing the sensed temperature for application to the fire control computer.

17. A method as claimed in claim 15 comprising providing an explosively inert material having a thermal conductivity and thermal mass substantially equal to the propellant and disposing it within a propellant container in a manner identical to the disposition of propellant material within such a propellant container.

18. A method as claimed in claim 16 or claim 17 comprising sensing the temperature of the explosively inert material at the core of the container.

19. A method as claimed in claim 18 comprising sensing the temperature of the explosively inert material at plurality of points at different depths from the surface and determining therefrom a temperature gradient of the inert material and an estinate of the temperature at a preferred burn zone position.

20. A method as claimed in any one of claims 16 to 19 including determining also the temperature of the container and the gun breech and in response to the difference between container and breech temperatures and the time of holding a propellant charge therein modifying the estimated temperature of the propellant charge.

21. A method of estimating the temperature of a propellant charge of a large calibre gun substantially as herein described with reference to, and as shown by Figures 3 and 4 of the accompanying drawings.

Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon) Ltd, Dd 8991685, 1987. Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.